6th Asian Academic Society International Conferenc (AASIC)
A Transformative Community:
Asia in Dynamism, Innovation, and Globalization

VETIVER GRASS AS PHYTOREMEDIATION FOR MINE TAILING ON TROPICAL RESIDUAL SOIL AT PONGKOR MOUNTAIN, WEST JAVA, INDONESIA

Rinaldo, Siagian[1], Muhamad, Maryudi[1], Verilla, Purba[1]

[1.] *Geological Engineering Department, Diponegoro University, Semarang, Indonesia*
Corresponding author's email: rinaldosiagian25@gmail.com

ABSTRACT

Tailing is residual material of valuable mineral extraction in ores processes, usually dump into residual soils which products of the intensive in-situ weathering of igneous, sedimentary and metamorphic rocks, and they include the group of iron-rich materials, usually described as laterites or lateritic soils which are very common in tropical areas. This research conducted by using method colecting data from soil and tailing characteristic by laboratorium scale and combine with previous research before. Generally, mining companies, especially gold mining in Pongkor Mountain, West Java is using NaCN compound in extraction processes. It is also appropriate by the geological characteristics in West Java that can produce residual soils. If the cyanide and the other heavy metal contents of tailings on Tropical Residual Soil produced exceeding the specified quantity standard, it would potentially damage the environment. This study is aimed to analyze the effectiveness of *C. zizanioides (L.)* or known as Vetiver Grass to decrease the concentration of the heavy metals (Cd and Cu) in residual soils as the contaminants from the tailings. The results indicated that the concentration of heavy metal waste (Cd and Cu) was decreasing along with the time exposure during the observation period. Using *C. zizanioides (L.)* effectively indicated removes metals Cd and Cu within 4 weeks with average removal efficiency are 37.64% (Cd1), 48.46% (Cd2.5) and 48.84% (Cd5) and 32.55% (Cu2.5), 54.68% (Cu5), and 52.59% (Cu7.5). This grass is also very easy to cultivate, so from the economic side will be very effective as phytoremediation. So it can be concluded the use of Vertiver Grass (C. *zizanioides* (L.) is very suitable to be done on residual soil in west java and can be used as role model for other regions that have the same residual soil characteristic in Indonesia.

Keywords: phytoremediation, mine tailing, vetiver grass, pongkor mountain

1. INTRODUCTION

Based on Law number 4 Year 2009 in Indonesia, mining has definition as partial or all of the phases of activities in the research, management and exploitation of minerals or coal which covering general investigation, exploration, feasibility study, construction, mining, processing and refining, transportation and sales, and post-mining activities. In addition to take benefit of natural resources itself, mining must be managed with consideration of the impact on the environment.

This research is located in Pongkor Mountain, West Java, Indonesia which is a mine gold that already discovered in 1981 and production commenced in 1994. The gold ore at Pongkor goes through various processes which include crushing, milling, cyanidation, carbon leaching and stripping, electro winning to melting and casting to produce dore. In the extraction process of gold from ore is done by leaching using NaCN (Sodium Cyanide). The extracted gold will then be recovered using activated carbon. Mud containing ores with uneconomical gold content will then become a waste called tailings. Tailings generally have a composition of about 50% of rocks and 50 %, water so they are slurry and are included in hazardous and toxic wastes, as they contain a variety of hazardous materials either from rocks or used when production is made.

Therefore, detoxification is needed to reduce and eliminate the effects of hazards on these tailings especially the cyanide content that should below the threshold limit value of 0.5 ppm in order to be safe for the environment. One of the potential method is Phytoremediation. Phytoremediation is a way of restoring balance with reduce the toxic content due to tailings in the gold mining area by using living plants. This study is adjusted to the soil characteristics of the area and review the use of Vertiver Grass as a feasible method of handling environmental problem caused by tailings.

2. EXPERIMENTAL METHOD

In writing of this research is made by comparing two or more variables. The data in the form of report of test result of tailing characteristic, soil characteristic and laboratory test result Vertiver grass. This data is processed based on an analysis of previous research data, books and other scientific journals combined with the author's idea, to propose the use of grass vetiver grass as an appropriate phytoremediation in the area of impact of tailing contents in Pongkor, West Java Province. Phytoremediation, also referred as botanical bioremediation (Chaney et al., 1997), involves the use of green plants to decontaminate soils, water and air. It is an emerging technology that can be applied to both organic and inorganic pollutants present in the soil, water or air (Salt et al., 1998). At metals contaminated sites, plants are used either to stabilise or remove the metals from the soil and ground water through mechanisms such as phytoextraction, rhizofiltration, and phytostabilization (UNEP 2002).

Phytoextraction also called phytoaccumulation, refers to the uptake and translocation of metal contaminants in the soil by plant roots into the aboveground portions of the plants. Rhizofiltration (rhizo- means root) is the adsorption or precipitation onto plant roots or absorption of contaminants in the solution surrounding the root zone. Rhizofiltration is similar to phytoextraction, but the plants are used primarily to address contaminated ground water rather than soil. The plants to be used for cleanup are raised in greenhouses with their roots in water rather than in soil. To acclimatize the plants, once a large root system has been developed, contaminated water is collected from a waste site and brought to the plants where it is substituted for their water source. The plants are then planted in the contaminated area where the roots take up the water and the contaminants along with

it. As the roots become saturated with contaminants, they are harvested. Phytostabilization is the use of certain plant species to immobilize contaminants in the soil through absorption and accumulation by roots, adsorption onto roots, or preqipitation within the root zone of plants (rhizosphere). This process reduces the mobility of the contaminant and prevents: migration to the ground water, and it reduces bio-availability of metal into the food chain. This technique can also be used to reestablish vegetation cover at sites where natural vegetation fails to survive due to high metals concentrations in surface soils or physical disturbances to surface materials. Metal-tolerant species is used to restore vegetation at contaminated sites, thereby decreasing the potential migration of pollutants through wind erosion and transport of exposed surface soils and leaching of soil contaminate onto groundwater.

Appropriate phytoremediation technologies and techniques applicable to different geographic regions with varied climatic conditions, site characterization, clean-up and technology selection criteria, assessment and evaluation methods that can determine the applicability of various phytoremediation techniques and capacity-building on the planning and implementation of phytoremediation technology.

3. CHARACTERISTICS

3.1 Tailing Characteristics

Tailings are a composite of fine-grained solid materials remaining after the metals and minerals are extracted from crushed and smoothed ores, as well as residual water of processing. But not 100% of the metals and minerals are extracted from the ore so that some are thrown into tailings. However, the content of metals and minerals in tailings is not economical. In addition, the deposited metal and mineral content of the ore is only a small part of the overall ore life. Most then become tailings. More than 99% of the processed mine (ore) material will become tailings especially if the ore has a low metal content. Thus, tailings become the mining waste with the largest volume (Lottermoser 2010). Tailings management is managing tailings throughout its life cycle, including production, transportation, placement, and storage, as well as the closure and rehabilitation of tailings storage facilities. Tailings as waste products from the mining industry usually have similar compositions to their original rocks. This is because the tailing is the original rock that has been taken precious metal. If traced, the gold processing process commonly conducted by mining companies in Indonesia is flotation and cyanidation. Flotation is a valuable metal floating process using froth and is a physics process so it is not used chemicals. While the cyanidation process is a selective dissolution process of metal by a particular solution, it usually uses cyanide (Prasetyo 2007). Tailings are generally composed of silica rock, clay, feldspar, calcite, calcium carbonate, and other soils. In addition to the original rocks, tailings also usually contain the remaining metal. Naturally, gold and silver mineralization coincide with the formation of other metal minerals formed as a counterpart mineral. The present minerals include Copper (Cu), Lead Black (Pb), Zinc (Zn), and

Iron (Fe) (Prasetyo, 2007). The composition and characteristics of different tailings in each mining unit. This depends on the characteristics of the ore rocks and the process of processing performed and the reagents. When a cyanidation process is used, tailings will inevitably contain cyanide of a certain amount that is harmful to the environment. The mineral mining industry is especially specialized in gold using large amounts of cyanide. This cyanide is used to extract minerals from ores. For the extraction of metals such as copper, nickel, cobalt, cyanide is used in the process of milling and concentration processes to separate the desired metal from waste. Cyanide is also used in some processes of synthesis of nylon, fiber, resin, and metallurgical processes so that it is contained in the discharged waste (Lordi, et al. 1980).

3.2 Soil Characteristics

The soil has no organic horizon with pH 6.97±0.3, soil humidity 10-21.67%, soil temperature 24.33-29.5^{o}C. The soil condition could vary locally depending on type of substrate, litter coverage, topography and shading and vegetation coverage. Table 1 shows another soil characteristic measured and how the soil has low macronutrient content, with standard on Hardjowigeno 1987), including nitrogen. In (Mitsch and Jorgensen 2004), it was stated that low nitrogen content was a characteristic of post mining land. The site landscape has the critical condition with value for land stability was 33.24%, water infiltration 37.2%, soil nutrient cycle 15.28% thus could not perform its regulation function (Sholihah, A.R.F., et. all 2014). These low values for stability and water infiltration were the major causes for erosion and land sliding in the area. On the other hands soil, rice straw and rice grain characteristic that found on West Java changed by ex-gold mining. Gold mining is carried out by individuals rather than companies in Junung Pongkor, West Java. They use traditional methods for separating the gold from the raw material. The main waste product from this process is mud and rubble which contain a high concentration of mercury. These wastes are disposed of directly in the Cikaniki river, which is also used as a source of irrigation water in the lowland rice areas around the mining areas. (Setyorini, D. et all 2016).

4. DATA

4.1 Vetiver Grass Characteristics

The following characteristics make vetiver an ideal species for environmental protection:

a. Stiff and erect stems, which form dense hedges when planted close together. These hedges can stand up to relatively deep water flows, reduce flow velocity and trap sediment (Truong et al. 1995)[1].
b. High resistance to pests, diseases and fire (West et al. 1996).
c. High tolerance to acidity, alkalinity, salinity, sodicity and magnesium (Truong and Baker 1997, 1998).

d. High tolerance to Al, Mn, As, Cd, Cr, Ni, Pb, Hg, Se and Zn in the soil (Truong 1999a; Truong and Baker 1998).
e. High tolerance to herbicides and pesticides (Cull et. 2000, Pinthong et al. 1998).
f. High efficiency in absorbing dissolved N, P, Hg, Cd and Pb in polluted water (Pinthong et al. 1998; Sripen et al. 1996).
g. Ability to grow again very quickly after being affected by the above adverse conditions once growing conditions have improved or soil ameliorants have been added (Truong et al. 1995).

4.2 Relation between Vetiver Grass and Cu Drops

Based on the experimental data with several types of samples in previous study, the process of plant maintenance was first acclimated to avoid contamination in the research which is part of phytoremediation process. According to (Minh and Khoa 2009), phytoremediation is an environmentally friendly technology for handling pollution and improving the environment. Then gives treatment, phytoremidiation process with soil that containing CuSO45H2O of 60 ppm, and continued with analysis of Cu content after 28 days using AAS obtained Reduction of Cu content on planting medium. It is shown in the following table:

Table 1. Concentration of Cu on Soil Before and After Phytoremediation (Sisilia, Livia,dkk. 2015)

Variety	Concentraion of Cu in Soil (ppm)		Removal Efficiency (%)
	Before	After	
Control (0 stem)	72.83	58.36[w]	19.86 [w]
4 stem	72.83	5.19x	92.87 x
8 stem	72.83	4.78y	93.46 y
12 stem	72.83	3.23z	95.56 z

Table 2. Concentration of Cu on Vetiver Before and After Phytoremediation (Sisilia, Livia,dkk., 2015)

Variety	Concentraion of Cu on Vetiver (ppm)		Removal Efficiency
	Awal	Akhir	(%)
Control (0 stem)	0	0	0 [w]
4 stem	0	43.81	60.15 [x]
8 stem	0	46.23	63.47 [y]
12 stem	0	52.61	72.23 [z]

It shows that concentration of Cu on soil as the Vetiver grass's media for 28 days decreased and happened the process of transfer Cu's ion from soil to plant so that concentration Cu on soil increase.

4.3 Relation between Vetiver Grass and Cd Drops

The result of concentration Cd analysis from previous analysis, after planting of vetiver with water as the medium for 4 weeks using AAS also found decrease of Cd concentration during observation.

Table 3. Concentration of Cd on Water Before and After Phytoremediation (Aryani, Desi 2015)

Time (week)	Concentration Cd in water (mg L^{-1})		
	Cd1[a]	Cd2.5[b]	Cd5[b]
0[a]	1,007±0,012	2,499±0,011	5,008±0,011
1[b]	0,690±0,182	1,216±0,204	2,791±0,229
2[b]	0,621±0,182	1,352±0,022	2,573±0,219
3 [b]	0,611±0,175	1,272±0,056	2,465±0,127

4 [b]	0,589±0,185	1,311±0,073	2,419±0,060

Superscript symbol means real differences on test level 5%

Table 4. Concentration of Cd on Vetiver Grass Before and After Phytoremediation (Aryani,Desi 2015)

Time (week)	Concentration Cd in vetiver (mg kg^{-1})		
	Cd1[a]	Cd2.5[b]	Cd5[b]
0	0	0	0
1	2.97	3.90	3.00
4	7.03	35.63	54.44

4.4 Relation between Vetiver Grass and CN Drops

The result of concentration CN^- after planting vetiver grass

Table 5. The remaining CN^- concentrations in water after treatment and the tolerance of vetiver grass

CN^- (mg/l)	CN^- conc in water (mg/l)	%removal Efficiency	Tolarance (week)
5	NDa	100a	8a
10	NDa	100a	8a
15	NDa	100a	8a
20	NDa	100a	6b
25	NDa	100a	6b
30	NDa	100a	
35	NDa	100a	5d
40	2.7d	93.4b	5d
45	3.1e	93,1b	5d
50	9.9g	80.3c	5d

Note. ND is non-detected for significance at 0.05 levels

4.5 Relation between Vetiver Grass and Others Heavy Metal Ion Drops

The result of concentration Cd analysis from previous analysis, after planting of vetiver with water as the medium for 10 days using AAS also found decrease of some heavy metal concentration during observation.

Table 6. Heavy metal reduction in water (mg/L) at different root lengths in Low Concentration (Suelee, Ashton L. 2015)

HeavyMetals/ Operation time (day)						
Root length	0	1	3	5	7	10
Fe:						
10 cm	0.86	0.65	0.47	0.36	0.29	0.04
20 cm	0.81	0.51	0.30	0.22	0.17	0.09
> 25 cm	0.85	0.55	0.28	0.22	0.18	0.10
Mn:						
10 cm	2.81	2.30	2.16	2.09	2.15	1.97
20 cm	2.79	2.34	2.18	2.14	2.17	2.00
> 25 cm	2.72	2.30	2.17	2.12	2.05	1.91
Pb:						
10 cm	0.72	0.54	0.44	0.37	0.38	0.31
20 cm	0.68	0.46	0.37	0.32	0.33	0.29
> 25 cm	0.60	0.39	0.31	0.32	0.22	0.21
Zn:						
10 cm	1.03	0.95	0.90	0.89	0.89	0.79
20 cm	1.01	0.95	0.91	0.89	0.85	0.76
> 25 cm	1.01	0.95	0.89	0.85	0.80	0.73

Heavy	Metals/ Removal efficiency (%)
Root length	

	0–1	0–3	0–5	0–7	0 – 10
Fe:					
	24.80	45.75	58.09	66.82	94.99
10 cm					
20 cm	36.80	63.32	73.11	78.69	89.47
> 25 cm	35.29	67.29	73.86	79.13	88.51
Mn:					
	18.24	23.22	25.76	23.51	30.16
10 cm					
20 cm	16.11	21.84	23.35	22.39	28.33
> 25 cm	15.36	20.30	22.07	24.43	29.68
Pb:					
	25.68	39.19	48.65	47.31	56.75
10 cm					
20 cm	32.85	45.71	52.86	51.42	57.15
> 25 cm	35.48	48.38	46.78	62.90	64.52
Zn:					
	7.43	12.03	13.57	13.42	22.89
10 cm					
20 cm	5.50	10.00	12.09	15.74	24.84
> 25 cm	6.37	12.35	16.03	20.65	28.15

5. Discussion

Based on an analysis of previous research data, books and other scientific journals combined with the author's idea which applying nitrogen fertilizer, found that mining in West Java also has residual material of valuable mineral extraction in ores processes called tailing. This tailing usually dumped into the soil that makes soil chemical composition changed. It also makes some heavy metal spread out in soil of our area, not only soil but also rice straw and rice grain. By choiceing vetiver grass, can decrease the hevay metal that we found in soil because vetiver grass has high tolerance with heavy metal and grow quickly so that makes more affectively to decreaseing contamination soil.

6. Conclusion

In conclusion the result shown in this paper that some of location in West Java has been contaminated by the heavy metal because ex-mining in there, not only the soil but also rice straw

and rice grain. This can be as alternative choiceing vetiver grass that high tolerant to heavy metals from mining tailing in west java. With longer vetiver grass planted, make it decrease composition of heavy metal in soil. Furthermore, it is very useful to apply nitrogen fertilizer when vetiver grass is used to re-vegetate the metalliferous mine wastelands.

6. Reference

Aryani Desy 2015 *Pemanfaatan Rumput Vetiver (Chrysopogon zizanioides, L.) dalam Proses Remediasi Logam Berat Kadmium (Cd) dan Tembaga (Cu). Tesis Magister*, IPB. Bandung.

Aschuri Ir. Imam, et all 2013 *Characteristics of Some Tropical Residual Soils on West Java*. Bandung. Itenas Library

Meeinkuirt W et all 2013 *Phytostabilization Potential of Pb Mine Tailings by Two Grass Species, Thysanolaena maxima and Vetiveria zizanioides* Water Air Soil Pollut. DOI 10.1007/s11270-013-1750-7.

Nanakorn Weerachai and Narong Chomcalow 2015 *Uses and Utilization of Vetiver*. Thailand. Ministry of Natural Resouces and Environment- Assumption University

Pang J. et. all 2003 *Physiological Aspects of Vetiver Grass for Rehabilitation in Abandoned Metalliferous Mine Wastes*. Hongkong.Chemosphere 52 1559-1570

Purwani, J 2010 *Remediasi Tanah dengan Menggunakan Tanaman Akumulator Logam Berat Akar Wangi (Vetiveria zizanioides L.). Prosiding Seminar Nasional Sumberdaya Lahan Pertanian*. Bogor.

Sisilia L Indah M Y, Wibowo N J 2015 *Pemanfaatan Tanaman Akar Wangi (Vetiver zizanioides (L.) Nash) untuk Penyerapan Logam Berat Tembaga (Cu). Journal UAJY*. LBL01223

Sholihah, A.R.F, et. all 2014 *Ecosystem Evaluation of Post Sand Mining Land in Cimalaka, Sumedang. Bandung*. Bandung Institute of Technology. ISSN: 2339-076X. Volume 1 Number 2:75-78.

Truong, Paul N V 2011 *The Global Impact of Vetiver Grass Technology on The Environment*, Australia, Queensland Departement of Natural Resources, Resouce Sciences Centre. DOI 10.1.1.557.217